Introduction to Symposium — Microbial Biomass: Measurement and Role in Soil Quality

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Soil microbial biomass (SMB) is one of the essential, living components of all terrestrial ecosystems. It regulates many critical ecosystem processes, including decomposition of organic materials, nutrient transformations and cycling, and biophysical integration of organic matter with soil solid, aqueous, and gaseous phases. Through its interactions with other organisms (e.g., soil fauna and plant roots), SMB also becomes vital in regulating the quantity and quality of components in the hydrologic cycle and in greenhouse gas emissions. Because of these attributes, SMB should be an integral part of a soil quality assessment.

Measurement of SMB, while always of interest to soil microbiologists, became an ever-increasing topic of scientific investigations with the development of the relatively simple, yet integrative protocol termed **chloroform fumigation–incubation (CFI)** (Jenkinson and Powlson 1976). The CFI method was an attempt to holistically quantify the entire soil microbial population as a single entity (Powlson 1994). Since the development of CFI, numerous other biochemical approaches have been developed to improve the characterization of the more active portion of the microbial community [e.g., substrate-induced respiration (Anderson and Domsch 1978), adenosine triphosphate (Oades and Jenkinson 1979), and arginine ammonification (Alef and Kleiner 1986)] and to reduce analysis time and quantify C, N, and other nutrient pools within the biomass [e.g., chloroform fumigation–extraction (Saggar et al. 1981; Brookes et al. 1982, 1985; Vance et al. 1987), ninhydrin reactive–extraction (Amato and Ladd 1988), rehydration–extraction (Sikora et al. 1994), microwave irradiation–extraction (Islam and Weil 1998), and hot water extraction (Sparling et al. 1998)].

The multitude of methods available to scientists today has created a quandary for those attempting to quantitatively integrate results across studies, laboratories, and regions into conceptual and ecosystem-process models. Observations that methods do not always produce similar magnitudes in estimates, nor correlate well across different soils and climatic regions, cause a dilemma for those of us trying to asses the "real" effect of management on SMB.

In the early months of 1997, Dr. Philip C. Brookes and I engaged in written discussion of the appropriateness of not subtracting a control when using CFI to determine SMB. His concern arose because numerous reports on SMB determined using CFI without subtraction of a control as a modification of the original method were appearing in the literature, leading to estimates of the SMB pool up to twice that with subtraction of a control (i.e., the original CFI method) (Wu et al. 1996). Size of the SMB pool has implications on microbial growth efficiencies, immobilization of C, N, and other nutrients, rates of turnover of SMB, microbial energetics, and modeling of soil organic matter dynamics. These discussions led colleagues at Texas A&M University and me to further explore several of our data sets collected under different environments, as well as data sets in the literature. We soon realized that not only were different sizes of SMB pools obtained with different methods of calculating SMB, but also more seriously, that different interpretations of the effect of management on SMB resulted (Franzluebbers et al. 1999).

At the suggestion of Dr. Brookes, I proposed to publicly address the issue of appropriate SMB methodology and relationship to soil quality assessment to Dr. Peter S. Bottomley, division chair of Soil Biology and Biochemistry of the Soil Science Society of America. We agreed to convene a symposium at the 90th annual meeting of the American Society of Agronomy in Baltimore, MD, on 21 October 1998. Dr. Harry H. Schomberg presided over four presentations, two of which are presented in these proceedings. Abstracts of the two presentations not in these proceedings can be found in Brookes (1998) and Smith (1998). One of the posters presented in conjunction with the symposium has been included in these proceedings.

The symposium aimed to cover two main topics:
(1) SMB measurement limitations and potentials,
(2) the role of SMB in assessing soil quality.

Presenters at the symposium were asked to address some of the following questions in order to stage a background for discussion among scientists attending the symposium: (i) Are some SMB measurements more appropriate than others? (ii) Under what conditions might some methods be more appropriate than others? (iii) Are SMB measurements well correlated with other biological, chemical, and physical properties of soils that might be important in soil quality assessment? (iv) Are precision, accuracy, robustness, rapidity, and simplicity important characteristics of SMB measurements and can any method exhibit of all these characteristics? (v) What level of precision is associated with various SMB measurements? (vi) Are SMB measurements sensitive to minor management changes that could affect soil functioning and, therefore, soil quality? (vii) How do SMB measurements currently fit into soil quality assessments by soil scientists? (viii) How could SMB measurements fit into soil quality assessments by integrative natural resource assessment teams that do not have particular expertise in soil biology? (ix) What are some of the management

systems identified using SMB measurements that have contributed to improvement or reduction in soil quality?

The symposium was well attended, with ~100 scientists at each of the presentations. Discussion on this topic was lively during and after the symposium. Dr. Martin R. Carter cautioned researchers to be aware of soil handling effects on SMB estimates, illustrated spatial and temporal patterns of SMB, and demonstrated the potential for using ^{13}C to discriminate sources of C utilized by SMB. Dr. Jeffrey L. Smith indicated that it is common to obtain negative SMB estimates when subtracting a control in the CFI method, illustrated the strong ties between C input and SMB on regenerating pyroclastic soils, and suggested that specific respiratory activity of SMB might be a more discerning variable to assess soil quality. Dr. Philip C. Brookes outlined the history of the CFI method, indicated that adenosine triphosphate determined under strongly acidic conditions only be used to validate SMB methods, and suggested that chloroform fumigation-extraction has become the method of choice for determining SMB. I concluded the symposium by illustrating that CFI without subtraction of a control is more related to other active soil C and N pools than CFI with subtraction of a control and by demonstrating that SMB using CFI without subtraction of a control is a sensitive assessment of biological soil quality in systems manipulated by soil disturbance and C input.

It is my hope that the symposium and its proceedings will inspire other scientists to look deeper into appropriate SMB methodology. The widely recognized work of Drs. David S. Jenkinson and David S. Powlson, and the many other soil microbiologists before them, has propelled soil biology to a much higher level than ever before. Unfortunately, many of the questions posed at this symposium have yet to be resolved. In the future, we must build upon these accomplishments by refining and standardizing SMB methodologies and developing equally holistic approaches based on rigorous and definitive techniques, perhaps through genetic characterization of various microbial communities. We must develop sensitive biological soil quality assessment tools, of which SMB should be a vital component, so that we can adequately characterize land management systems and promote those that are the most sustainable.

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